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ACCEPTANCE CRITERIA FOR FOAMED-CEMENT WALL SYSTEMS

AC91
September 1993

Revised May 1995*

PREFACE

Evaluation reports issued by the ICBO Evaluation Service, Inc. (ICBO ES), are based upon performance features of the *Uniform Building Code*[™], *ICBO Uniform Mechanical Code*[™] and related codes. Section 104.2.8 of the Uniform Building Code is the primary charging section upon which evaluation reports are issued. Section 104.2.8 reads as follows:

The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.

The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.

The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

The attached acceptance criteria for the general code sections noted have been issued to provide all interested parties with guidelines on implementing performance features of the codes. The attached acceptance criteria were developed and adopted following public hearings conducted by the Evaluation Committee. These criteria may be revised from time to time as the need dictates.

ICBO ES may consider alternate criteria, provided the proponent submits valid data demonstrating that the alternate criteria are at least equivalent to the attached criteria and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a material, type or method of construction, or equipment, meets the attached acceptance criteria, or it can be demonstrated that valid alternate criteria are equivalent and otherwise meet the applicable performance requirements of the codes, if the material, product, system or equipment is such that either unusual care with its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use thereof, ICBO ES retains the right to refuse to issue or renew an evaluation report.

Published by the

International Conference of Building Officials

5360 WORKMAN MILL ROAD • WHITTIER, CALIFORNIA 90601-2298

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PRINTED IN THE U.S.A.

*Editorially revised to reflect 1994 code references.

ACCEPTANCE CRITERIA FOR FOAMED-CEMENT WALL SYSTEMS

1. INTRODUCTION

1.1 Scope:

The purpose of this document is to specify the conditions under which foamed-cement wall systems can be recognized in an ICBO Evaluation Service, Inc. (ICBO ES), evaluation report under the Uniform Building Code (code). Basis of recognition is Section 104.2.8 of the code. Foamed-cement wall systems are jobsite constructed, reinforced walls. The foamed-cement is field cast as horizontal panels that are lifted after curing and placed as one-story exterior and interior bearing and shear walls not exceeding 12 feet in height for use in combustible construction. Maximum and minimum wall panel lengths are 20 and 2 feet, respectively. Maximum and minimum wall panel thicknesses are 12 and 7¹/₂ inches, respectively. Exterior walls are covered with a two-coat application of exterior plaster as specified for applications over concrete in Section 2508.1 of the code. Interior wall surfaces are covered with a two-coat application of interior plaster as specified in Section 2507 of the code.

2. DEFINITIONS

2.1 Air Entraining Agent:

A proprietary liquid used as a component to cause the cured foamed-cement to be cellular in composition.

2.2 Hardening Agent:

A proprietary liquid used as a component to harden the foamed-cement.

2.3 Foamed-Cement:

Air entraining and hardening agents are field mixed with Type I/II or Type II portland cement complying with U.B.C. Standard 19-1, and water in a special paddle mixer. The resulting mix is poured into horizontal forms and allowed to cure as required for concrete. Cured foamed-cement has an oven-dry density of 35 ± 5 pcf and a minimum 28 day compressive strength of 300 psi.

2.4 Reinforcement:

Plain or deformed steel welded-wire fabrics complying with ASTM A 185-90a and A 497-90b, respectively. Reinforcement is symmetrically placed and located in each face of wall.

2.5 Fastening System:

Method used to mechanically attach cured wall panels to the foundation, adjacent panels and roof-ceiling framing. The system includes steel angles and plates, sheet metal screws and embedment of wall reinforcement into the foundation.

3. BASIC INFORMATION

The following basic information needs to be furnished:

3.1 Air Entraining and Hardening Agents Product Description:

Description of material including weight, packaging, labeling and shelf life.

3.2 Mixing, Pouring and Curing Instructions:

Instructions pertinent to the mixing, pouring and curing of the foamed-cement including dosage rates, methods of mixing, reinforcement placement and form work dimension limitations.

3.3 Installation Instructions:

Instructions pertinent to installation and connections involving the cured foamed-cement panels. Joint treatment, flashing and methods of attachment of exterior and interior finishes must also be included.

4. TESTING AND REPORTING

4.1 Samples:

Test specimens must be prepared using products that are of standard manufacture and representative of products on which recognition is sought. The test laboratory shall randomly sample the air entraining, foaming and hardening agents to be used in tests from the manufacturer's facility or purchase the products on the open market.

4.2 Testing Laboratory:

All tests must be conducted by an ICBO ES recognized independent testing laboratory at the testing laboratory facility. A qualified representative of the test laboratory must witness preparation of, or prepare specimens and conduct the tests.

4.3 Test Reports:

Test reports must be prepared by the independent test laboratory and comply with the ICBO ES Acceptance Criteria for Test Reports.

5. REQUIRED DATA

5.1 Physical Property Tests:

Physical property tests in Section 6.1 must be performed on each batch of foamed cement used to prepare test specimens for structural tests in Section 5.2

5.2 Structural Performance Tests:

5.2.1 General:

5.2.1.1 Recognition of foamed-cement walls is limited to materials and sizes used in tests. Sizes recognized shall not exceed the limitations noted in Section 1.1.

5.2.1.2 Oven dry density of cured foamed-cement used in test specimens shall not exceed 32 pcf.

5.2.1.3 Load test specimens must be supported in a manner consistent with connection details intended for field installation.

5.2.1.4 Voids in walls for electrical outlet boxes and raceways are permitted, provided they are included in test specimens.

5.2.1.5 A series of three tests are required for each test type and combination of wall thickness, height and reinforcement. For nonsymmetrical construction, additional load test series are needed. Allowable transverse and axial loads may be used for shorter spans or heights, but extrapolation is not permitted. In addition to testing maximum spans, tests of minimum spans are necessary to develop sufficient data to permit interpolation of loads and spans. Method of interpolation must be approved by ICBO ES.

5.2.1.6 Each test result shall not vary more than 15 percent from the average of the series unless the lowest value is used in determining the allowable load.

5.2.1.7 Where tests are not conducted to failure, the highest load achieved for each test will be assumed as ultimate.

5.2.1.8 Three physical property compression test specimens shall be tested for each wall test series in accordance with Section 6.1 within 48 hours of wall tests for correlation of material properties to wall test results. In addition, specific gravity tests shall be conducted on the cured material used to prepare structural test specimens.

5.2.2 Transverse and Axial Load Tests: Transverse and axial load tests must be conducted in accordance with Sections 6.2 and 6.3, respectively, and Section 5.2.1. The allowable service load of each test series shall be the lesser of the following unless the analysis of test data indicates a deviation from generally accepted engineering principles, resulting in a larger safety factor and/or stricter deflection limitations:

5.2.2.1 Average ultimate load divided by a safety factor of 3.

5.2.2.2 Average load at tested out-of-plane deflection of $L/240$ of the span.

5.2.2.3 Average load recorded at first cracking or spalling of specimens.

5.2.3 Combined Axial and Transverse Loads: Flexural-compression tests shall be conducted in accordance with Sections 5.2.1 and 6.4. A minimum of two series of tests are needed. The first series shall be conducted with an axial load of two-thirds the ultimate load while simultaneously applying transverse incremental loading to failure. The second series shall be conducted with an axial load of one third of the ultimate load with simultaneous application of incremental transverse loading. An analysis of the flexural-compression, axial and transverse load tests shall develop the relationship for combining axial and transverse loads.

5.2.4 Racking-shear Tests: Racking shear tests shall be conducted in accordance with Sections 5.2.1 and 6.5. Specimens shall be tested at the maximum height to width ratio that is to be considered. The allowable service load of each test series shall be the lesser of the following:

5.2.4.1 Average ultimate load divided by a safety factor of 3.

5.2.4.2 Average load recorded at first cracking or spalling of specimen.

5.2.4.3 Average load at a net horizontal deflection of $\frac{1}{2}$ inch.

5.2.5 Cyclic-load Racking Shear Tests: Cyclic-load racking shear tests shall be conducted in accordance with Sections 6.6 and 5.2.1 with the exception that Subsections 5.2.1.5 and 5.2.1.6 are not applicable. The conditions of acceptance are as follows:

5.2.5.1 The average ultimate load of the two specimens shall be at least equal to 90 percent of the average ultimate load of the identical specimens tested under Section 5.2.4.

5.2.5.2 Deflection of the specimens subjected to allowable load at the 50th cycle shall not exceed $\frac{1}{2}$ inch or the deflection at the first cycle by more than $\frac{1}{8}$ inch, whichever is less.

5.2.5.3 Deflection of the specimens subjected to allowable load shall not cause a crushing exceeding the crushing strain of the foamed cement.

5.2.5.4 The zero load deflection at the 50th cycle shall not exceed $\frac{1}{16}$ inch.

5.3 Durability:

5.3.1 Freezing and Thawing:

5.3.1.1 General: Freezing and thawing tests shall be conducted in accordance with Section 6.7.

5.3.1.2 Conditions of Acceptance: Individual specimen weight loss cannot exceed 1 percent of original weight. In addition, evidence of cracking, checking, crazing, erosion or other characteristics that may effect performance when viewed under 5X magnification are not permitted.

5.3.2 Drying Shrinkage:

5.3.2.1 General: Shrinkage tests shall be conducted in accordance with Section 6.8.

5.3.2.2 Conditions of Acceptance: Average drying shrinkage of three specimens must not exceed 0.20 percent.

5.3.3 Corrosion of Reinforcement:

5.3.3.1 General: Corrosion of reinforcement tests shall be conducted in accordance with Section 6.9.

5.3.3.2 Conditions of Acceptance: Performance of the foamed cement must be equivalent to the control specimens.

5.4 Weather-resistive Considerations:

A weather-resistive barrier complying with Section 1402.1 of the code is required, or the water penetration tests of Section 6.10 shall be conducted with the conditions of acceptance of no dampness on the unexposed side of any test assembly.

5.5 Interior Finish:

Interior finish of wall must have flame-spread and smoke-density ratings as specified in Section 802 of the code. Foamed-cement wall panels must have a minimum Class III flame-spread classification and smoke density not exceeding 450 when tested under U.B.C. Standard 8-1. To determine the effect of thickness on flame-spread and smoke density, an analysis of tests conducted on 1- and 5-inch-thick foamed-cement test specimens shall be prepared by the testing laboratory extending the results of tests to the maximum panel thickness under consideration. The oven-dry density of the foamed-cement test panels must be recorded. The effect of density on flame-spread and smoke density must be addressed by the test laboratory.

5.6 Quality Control:

A quality control manual for the manufacture of the air entraining and hardening agents must be developed in consultation with an ICBO ES or NES recognized quality control agency responsible for follow-up inspections. The manual must comply with the ICBO ES Acceptance Criteria for Quality Control Manuals.

5.7 Field Inspection Manual:

A manual containing the manufacturer's jobsite construction procedures and testing requirements shall be submitted and a copy shall be available at the jobsite at all times during construction. As a minimum, the manual must include the following:

5.7.1 Title and date.

5.7.2 Shelf life information on air entraining and hardening agents.

5.7.3 Description of field tests to verify quality of air entraining and hardening agents prior to use.

5.7.4 Method of placing, supporting and tying steel reinforcement into position.

5.7.5 Method of mixing and pouring of foamed-cement mix.

5.7.6 Description and conditions of acceptance of field tests of foamed-cement mix, i.e., air content, wet density and pH of water.

5.7.7 Method of preparing specimens for laboratory tests of foamed-cement.

5.7.8 Laboratory test procedures and conditions of acceptance for physical property tests of Section 5.1 of this criteria.

5.7.9 Curing instructions.

5.7.10 Special inspector instructions.

5.8 Fire-resistive Construction (Optional):

Tests for fire-resistive construction must be conducted in accordance with U.B.C. Standard 7-1.

5.9 Thermal Conductivity (Optional):

Tests for thermal conductivity must be conducted in accordance with ASTM C 236.

6. TEST PROCEDURES

6.1 Physical Property Tests:

The physical property tests are to be conducted in accordance with the corresponding test method noted in Table 1.

6.2 Transverse Load Tests:

Wall transverse load tests are conducted in accordance with the general guidelines of ASTM E 72 using two-point loading (quarter points) except the specimens are to be supported in accordance with Section 5.2.2.

6.3 Axial Load Tests:

Wall compressive load tests are conducted in accordance with the general guidelines of ASTM E 72 with the load applied with an eccentricity of one-sixth the wall thickness. Bearing pads shall be used between applied loads and test specimen with the pads replicating details of field installations.

6.4 Flexural-compression Tests:

Flexural-compression tests of walls are conducted in accordance with the general guidelines of ASTM E 72 with axial and transverse loads simultaneously applied to specimens.

6.5 Racking-shear Tests:

Racking-shear tests of walls are conducted in accordance with the procedures developed for sheathed wood frames described in ASTM E 72 with the following exceptions:

6.5.1 Test specimens shall be mounted on a base and connected in a manner equivalent to the method commonly used in the field.

6.5.2 The horizontal timber suggested for the top of the test panels shall not be used. The racking shear load should be applied directly against the typical wall panel top plate member or members that duplicate actual field construction.

6.5.3 The holddown rods described in ASTM E 72 shall not be used.

6.6 Cyclic-load Racking Shear Tests:

Tests are to be conducted on two specimens identical to the assemblies tested under Section 5.2.4, including holddowns, if any. A racking shear load shall be applied as described in Section 6.5 except the applied load is cyclic with load direction reversal. The cycle consists of an initial load application equal to 100 percent of the allowable racking shear load determined under Section 5.2.4, load removed, 100 percent allowable load applied in the direction opposite to the initial load and load removed. This cycle of load reversal is repeated for a minimum of 50 cycles. Deflection shall be recorded at each load level of each cycle. After completion of 50 cycles, the specimens are subjected to an increasing racking shear load to failure. This load is applied in the direction of the initially applied load.

6.7 Freezing and Thawing:

A total of nine samples are cut from wall panels used in the structural tests. Sample size shall be the wall panel thickness by 6 inches by 6 inches.

Initial specimen weights are recorded. The specimens are dried at 240°F. ± 10°F. for a minimum of 24 hours in a well ventilated oven. Dry weights are recorded. All specimens are submerged in water at 77°F. + 5°F. for 48 hours and saturated weight recorded. Specimens are then placed in a tray containing water. Water depth shall be 1/2 inch with specimens held in place. The first set of three specimens are placed with the wall cross section surface in the water. The second set of three specimens are placed with the 6-inch by 6-inch exterior wall surface in the water. The final three specimens are placed with their 6-inch by 6-inch interior wall surface in the water. The tray and specimens are put in a freezer maintained at 16°F. ± 4°F. for 20 hours with the requirement that the specimens freeze within 14 hours. The specimens are removed from the freezer and thawed in water at 77°F. + 5°F. for four hours. The cycle of freezing and thawing shall be repeated for 50 cycles. After completing of 50th cycle, the specimens are dried in the oven as noted above. Dry weight shall be recorded.

6.8 Drying Shrinkage:

Drying shrinkage tests are conducted in accordance with ASTM C 341. Three samples are cut from a structural panel test specimen that is unreinforced or does not have steel parallel to the drying shrinkage test specimen length. As an alternative, three samples are cast without reinforcement from the same batch of foamed cement used to produce the structural panel test specimens. The specimens shall be 2 inches by 2 inches in cross section and of sufficient length to provide a minimum 10 inch gage length. After curing, all specimens are conditioned by immersion

in water at 75°F. ± 3°F. for 48 hours. Length measurements commence immediately under removal from water.

6.9 Corrosion of Reinforcement:

Four foamed-cement samples and four concrete (control) samples are to be cast and cured. The size of all specimens is 12 inches wide by 6 inches deep by 12 inches long. Three No. 4 uncoated steel reinforcing bars shall be in each specimen with the intended coverage. Control specimens shall be normal-weight, nonair-entrained concrete having a water cement ratio complying with U.B.C. Table 19-A-2 and a 28-day compressive strength of 2,500 psi. Two foamed-cement and two control specimens are saturated in a solution of 10 percent salt for 48 hours. The remaining specimens are conditioned in controlled laboratory conditions of 70°F. ± 5°F. and 50 percent ± 5 percent relative humidity. At the end of the conditioning and exposure periods, all specimens are tested in accordance with ASTM C 876.

6.10 Water-penetration Test:

The water-penetration test shall be conducted on at least three specimens in accordance with ASTM E 514 with exceptions noted herein. The specimens shall consist of foamed-cement and steel reinforcement without wall coverings. The thickness of specimens shall represent the minimum wall thickness. Specimen age shall be minimum 28 days with curing in accordance with the manufacturer's instructions. The duration of the test is four hours with water applied at a rate of 5 gallons per square foot per hour. The chamber pressure shall be maintained for the duration of the test and be equal to 10 percent of the maximum allowable transverse load from Section 5.2.2 or 2 inches of water column, whichever is greater. Condition of the specimen shall be recorded every 30 minutes for the first two hours and every hour, thereafter.

Oven-dry density tests shall be conducted on the cured material used to prepare the water-penetration test specimens.

6.11 Seismic Considerations:

Additional testing may be required to correlate foamed-cement wall systems with concrete wall systems under Sections 1627.6 and 1921 of the code.

7. MISCELLANEOUS**7.1 Special Inspection:**

Special inspection in accordance with Section 1701.6 of the code and the field inspection manual of Section 5.7 of this criteria is needed.

7.2 Plans, details, specifications, etc., concerning proper installation of the system that are applicable to specific buildings under consideration, must be a part of plans submitted to the building department for approval.

7.3 Door and Window Openings:

Axial, transverse and/or racking loads at door and window openings shall be supported by conventional materials designed in accordance with the code.

7.4 Plumbing and waste lines are not permitted within the foamed concrete wall.

7.5 Minimum ratio of steel reinforcement area to gross wall area shall be 0.0006.

7.6 Minimum thickness of foamed cement coverage of steel reinforcement is 1 1/4 inches.

7.7 Foamed-cement walls shall not be exposed to sulfate-containing solutions or soils.

7.8 Foamed-cement shall be protected from free water until covered with exterior plaster.

TABLE 1—PHYSICAL PROPERTY TESTS

ITEM NO.	PROPERTY	NO. OF SPECIMENS	TEST METHOD
1.	Compressive Stress ¹	4 ²	ASTM C 495 or C 513
2.	Oven Dry Density	5	ASTM C 642
3.	Water Absorption	5	ASTM C 642
4.	Tensile Strength Perpendicular to Surface	5	ASTM C 209
5.	Flexural Strength	10 ³	ASTM C 78
6.	Modulus of Elasticity	5	ASTM C 469-87a
7.	Poisson Ratio	5	ASTM C 469-87a

¹Wet density and air content tests of the batch of foamed-cement used to produce the compression test specimens shall be conducted. The method used to determine the wet density shall be reported. Air content tests shall conform to ASTM C 796.

²Determine compressive stress with 6-inch-diameter by 12-inch cylinder specimens according to ASTM C 39.

³Determine flexural strength for two conditions. For Condition A, the specimen size is 3 inches wide by 1 inch thick by 14 inches in length with a test span of 12 inches. Other specimen proportions may be used, provided the test span is minimum 12 times the depth. For Condition B, the specimen size is the same as Condition A, except the test span is 4 inches. The depth-to-span ratio must be a maximum of 4. Ten specimens for each condition are required.